Executive Summary

WASTEWATER CHALLENGES IN SOUTH FLORIDA

Every day, more than 1.5 billion gallons of wastewater leave municipal treatment facilities in Florida bound for reuse or disposal. Municipalities in South Florida rely less on discharges to surface waters and more on reuse, ocean discharge and deep-well injection. For example, in Miami-Dade County, for every three gallons of wastewater generated, one gallon is treated and sent to deep underground saltwater formations. The other two gallons are piped out to the ocean, three and a half miles offshore. In dry-weather conditions in Pinellas County, for every three gallons of wastewater generated, all three gallons are reclaimed to golf courses, parks, and lawns after high-level treatment and disinfection. However, the Pinellas area receives on average forty-eight inches of rain annually, and deep-well disposal is heavily relied on as the backup during wet weather.

Each municipality in South Florida is faced with its own particular challenges to ensure, safe reuse and disposal of wastewater, safe drinking water and a healthy environment for its 5.8 million residents. Local municipalities are struggling to make sound wastewater management decisions, taking into account the often overwhelming complexities and the range of technical issues associated with different reuse and disposal options.

The State is strongly committed to protecting its surface waters, such as lakes, rivers, streams, wetlands, estuaries, and the ocean. It is equally committed to protecting the highly permeable aquifer systems that provide 94% of the area's drinking water. A major challenge to protecting water resources is Florida's growing population and the accompanying need for safe drinking water, safe reclaimed water reuse, and safe wastewater disposal.

The Environmental Protection Agency (EPA) has established minimum requirements for Class I municipal wells and other underground injection activities through a series of Underground Injection Control (UIC) regulations at Code of Federal Regulations (CFR) Title 40 Parts 144-147, developed under the authority of the Safe Drinking Water Act. These regulations ensure that Class I municipal wells will not endanger USDWs by prohibiting the movement of any contaminant into Underground Sources of Drinking Water (USDW).

On July 7, 2000, EPA proposed revisions to the UIC regulations that would allow continued wastewater injection by existing Class I municipal wells that have caused or may cause movement of contaminants into USDWs in specific areas of Florida (65 FR 42234). Continued injection would be allowed only if owners or operators meet certain requirements that provide adequate protection for USDWs. In the alternative, if new requirements are not promulgated, owners and/or operators of wells targeted by the proposal would be required to close their wells and adopt different wastewater disposal practices, which could consist of surface water disposal, ocean outfall, and/or reuse. Use of these alternative disposal practices would likely require the construction of systems for advanced wastewater treatment, nutrient removal, and high-level disinfection.

CONGRESSIONAL MANDATE FOR RELATIVE RISK ASSESSMENT

EPA, as directed by congressional language in its fiscal year 2000 appropriation, prepared the relative risk assessment presented in this report:

> *Within available funds, the conferees direct EPA to conduct a relative risk assessment of deep well injection, ocean disposal, surface discharge, and aquifer recharge of treated effluent in South Florida, in close cooperation with the Florida Department of Environmental Protection [DEP] and South Florida municipal water utilities.*

Congress directed EPA to conduct this assessment because wastewater injected into deep wells had moved from where it was supposed to be confined to areas where it is prohibited. Congress directed EPA to conduct the relative risk assessment to shed light on the risks posed by fluid movement from deep injection and relate those risks to risks posed by treated effluent from other wastewater management options.

MUNICIPAL WASTEWATER TREATMENT OPTIONS IN SOUTH FLORIDA

To capture all counties with deep-well injection, the South Florida area considered in the relative risk assessment extends south from a line drawn from the northern end of Brevard County on the east coast to the northern end of Pinellas County on the west coast (Exhibit ES-1).

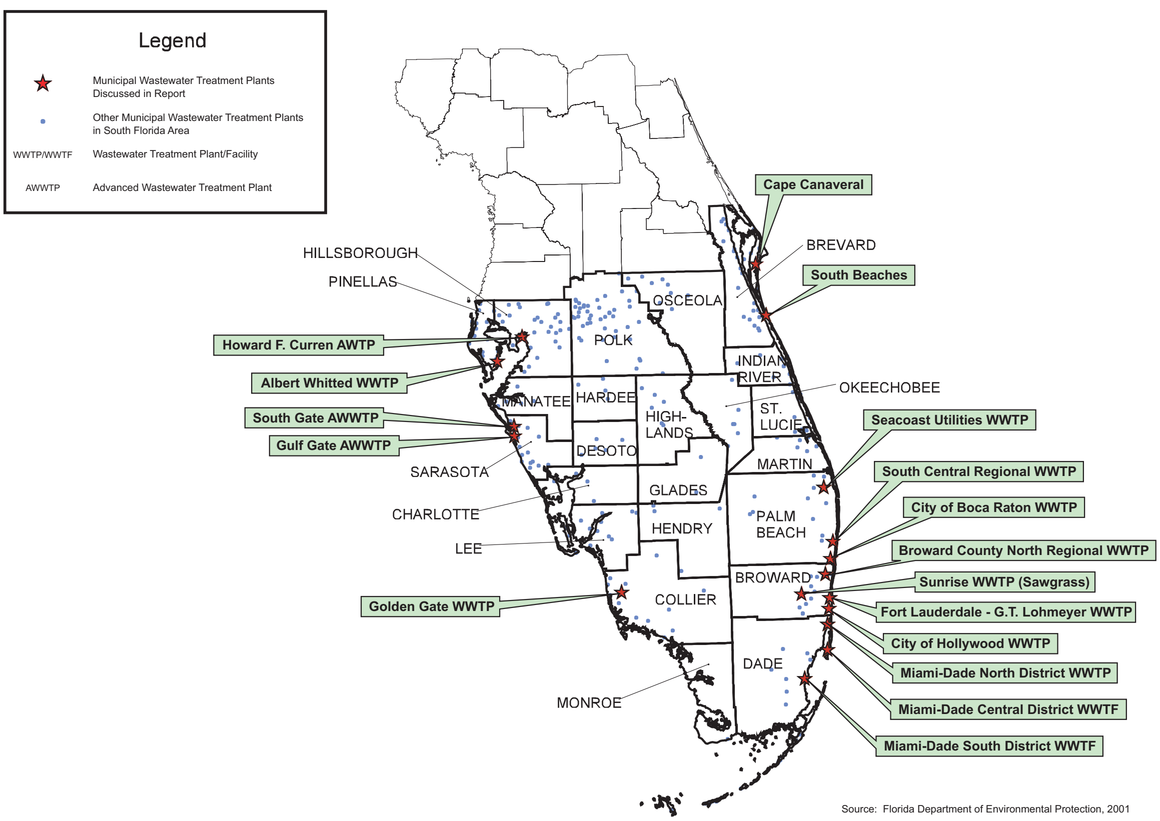


Exhibit ES-1. Municipal Wastewater Treatment Plants in South Florida

Wastewater Treatment Options

Florida primarily uses four options for the management of treated municipal wastewater (Exhibit ES-2):

- **Deep-well injection:** Wastewater is injected by gravity flow or under pressure into deep geological strata below USDWs. Under EPA and State UIC program regulations Class I wells inject fluids beneath the lowermost formation containing a USDW.
- **Aquifer recharge:** Reclaimed water is discharged to land application systems, such as infiltration basins and unlined ponds.
- **Discharge to ocean outfalls:** Treated wastewater is discharged to the ocean via outfall pipes that may extend from almost 1 mile to more than 3.5 miles from shore.
- **Discharge to surface-water bodies:** Wastewater is discharged into canals, creeks, and estuaries.

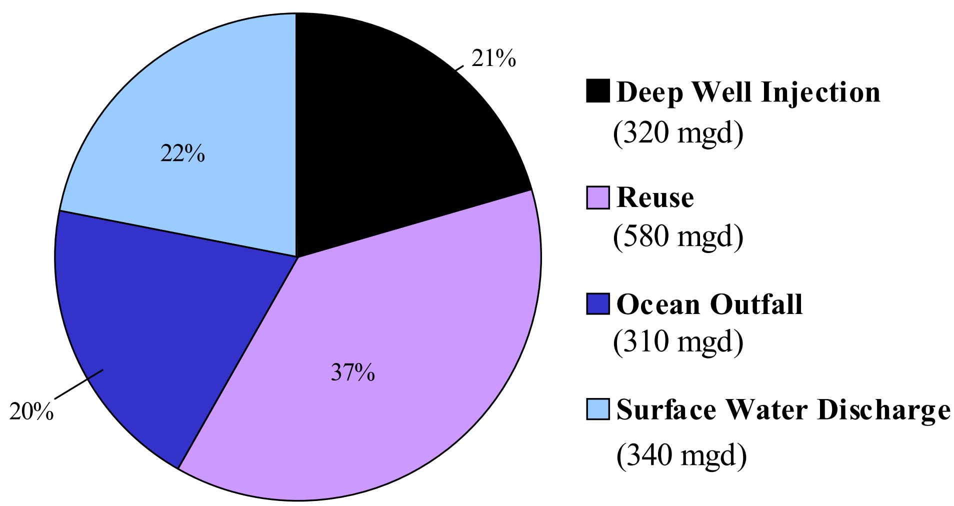


Exhibit ES-2. Use and Disposal of Effluent and Reused Water in Florida[1]

Although the term ***option,*** used to describe the wastewater treatment methods, suggests any of these are available for use by municipalities in South Florida, in fact most municipalities are limited by a variety of critical local conditions, governing regulations and costs in evaluating possible treatment methods. (Exhibit ES-3).

[1] This chart uses data for the entire state of Florida. No specific data was available for the study area only. The distribution of waste treatment options within the study area is likely to be different than that presented in this chart (i.e. all ocean disposal and deep underground injection is in the Study area and there is much less use of surface water disposal in South Florida).

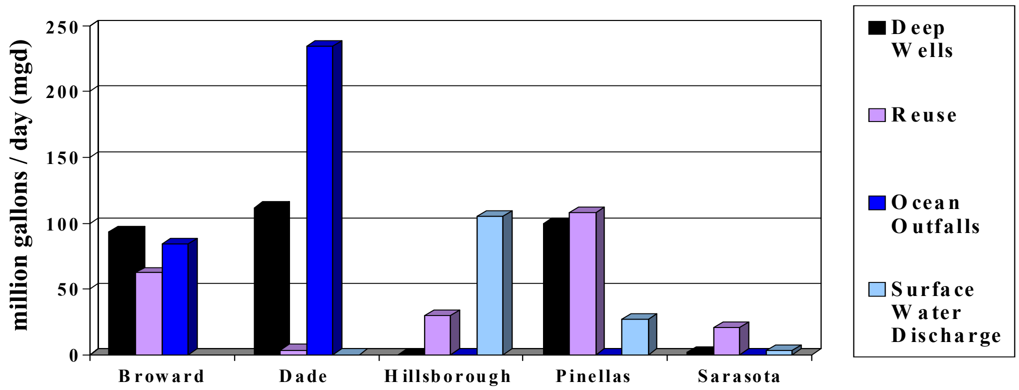


Exhibit ES-3. Wastewater Management for Selected Counties in South Florida

Levels of Wastewater Treatment and Disinfection

Wastewater treatment facilities in South Florida combine various levels of wastewater treatment and disinfection to arrive at effluent concentrations that are appropriate for the local conditions and that comply with State and EPA requirements.

- **Primary Treatment** is a basic treatment process that removes material that will float or settle.
- **Secondary Treatment** is a process in which bacteria consume the biodegradable organic matter and remove suspended solids using chemical and biological processes. The success of treatment may be quantified by its ability to remove Biochemical Oxygen Demand (BOD) and Total Suspended Solids (TSS).
- **Reclaimed Water** in Florida means water has received at least secondary treatment and is reused. Some uses require high-level disinfection that includes filtration.
- **Advanced Water Treatment** (AWT) refers to treatment beyond secondary but in Florida it has specific regulatory meaning for a combination of treatments that includes secondary treatment, high-level disinfection, nutrient removal, and removal of toxic compounds (usually by filtration). AWT is used if there are requirements to remove specific components, such as nitrogen and phosphorus, which are not removed by secondary treatment alone.
- **Disinfection** is the selective destruction of pathogens. The State regulations define basic, intermediate and high-level disinfection with levels of filtration and bacterial deactivation.

Each of the four wastewater management options (deep-well injection, ocean outfall, aquifer recharge, and surface water discharge) provide different levels of treatment and disinfection, depending upon regulatory and site-specific needs. The levels for Biochemical Oxygen Demand, (BOD), Total Suspended Solids (TSS), Total Nitrogen (TN), and Total Phosphorus, (TP) shown in Exhibit ES-4 are required for some required discharges and do not apply universally to all (see Chapters 62-600 and 62-610 F.A.R.).

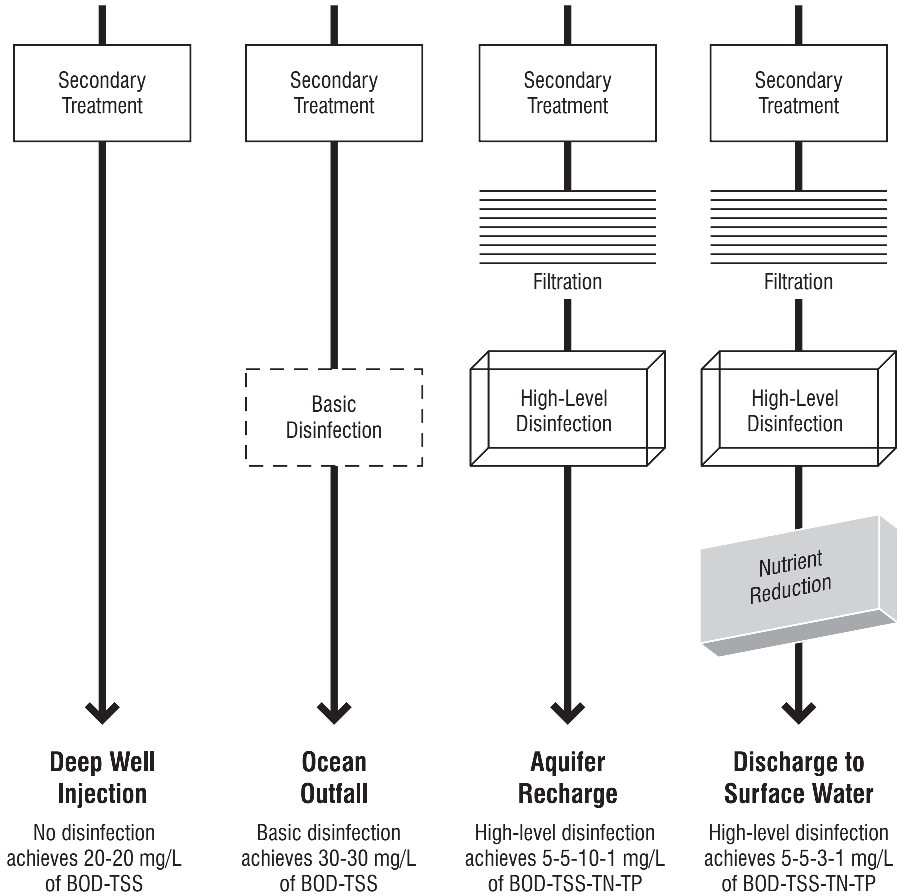


Exhibit ES-4. Levels of Treatment and Disinfection for the Four Disposal Options

RISK ASSESSMENT

Risk assessment is a multistep process. It evaluates the likelihood that adverse human health or ecological effects will occur as a result of exposure to stressors. A ***stressor*** is any physical, chemical, or biological entity that can induce an adverse response. The organism, population, or ecosystem exposed to a stressor is referred to as a ***receptor.*** ***Exposure*** refers to the contact or co-occurrence of a stressor and receptor. If there is no contact or co-occurrence between the stressor and the receptor, then there is no risk.

Risk characterization is the culminating step of the risk assessment process. It conveys the risk assessor's judgment about the existence of human health or ecological risks and their nature (US EPA, 2000). Information from the risk assessment steps is integrated and synthesized into an overall conclusion about risk that is informative and useful for decision-makers and for interested and affected parties.

Approach Used in This Relative Risk Assessment

The risk assessment conducted by EPA involved investigating four very different wastewater disposal options: deep-well injection, aquifer recharge, discharge to ocean outfalls, and discharge to surface-water bodies. Each option has its own specific stressors (hazards), exposure pathways, receptors, and effects.

Data from many sources were used to support the analyses and evaluations. Risk characterization for each wastewater treatment option included identifying and describing the associated risks, the potential magnitude of the risks, and potential effects on human and ecological health. The relative risk assessment then described and compared risks for all four wastewater management options.

This relative risk assessment first used a generalized approach to describe potential risks and identify possible stressors, sources, exposure pathways, and effects on receptors. This step incorporates human health and ecological risk components and provides a conceptual model of potential risk. A conceptual model was developed for each of the four disposal options. Exhibit ES-5 is an example of a conceptual model of potential risks developed for the relative risk assessment. Potential system stressors, exposure pathways, receptors, and the potential effects on receptors are identified in the model.

To assess the risks and to allow comparisons, EPA conducted individual risk assessments for each wastewater disposal option, and the risks associated with each were characterized. The risks and risk factors identified in each disposal option were then evaluated and described. The overall comparisons and conclusions are presented as relative risk assessment matrices. EPA found that the parameters that are relevant to one particular disposal option are not necessarily relevant to the remaining three. Therefore, a strictly quantitative comparison between the four options was not feasible.

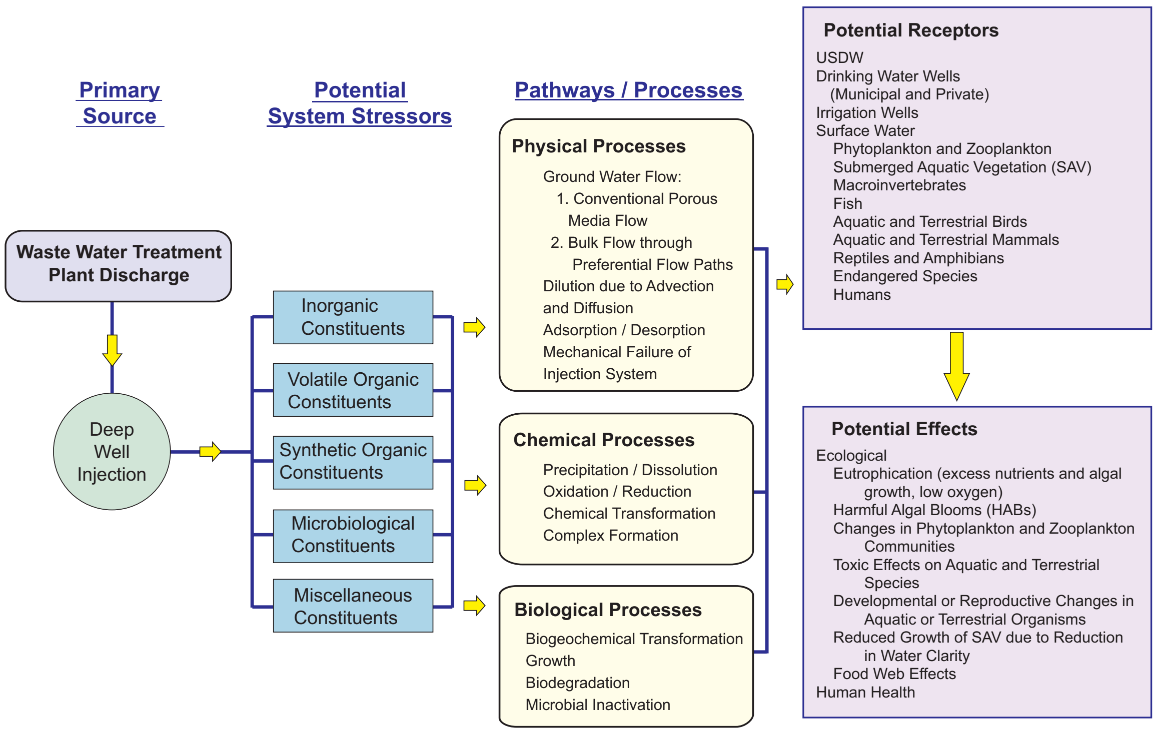
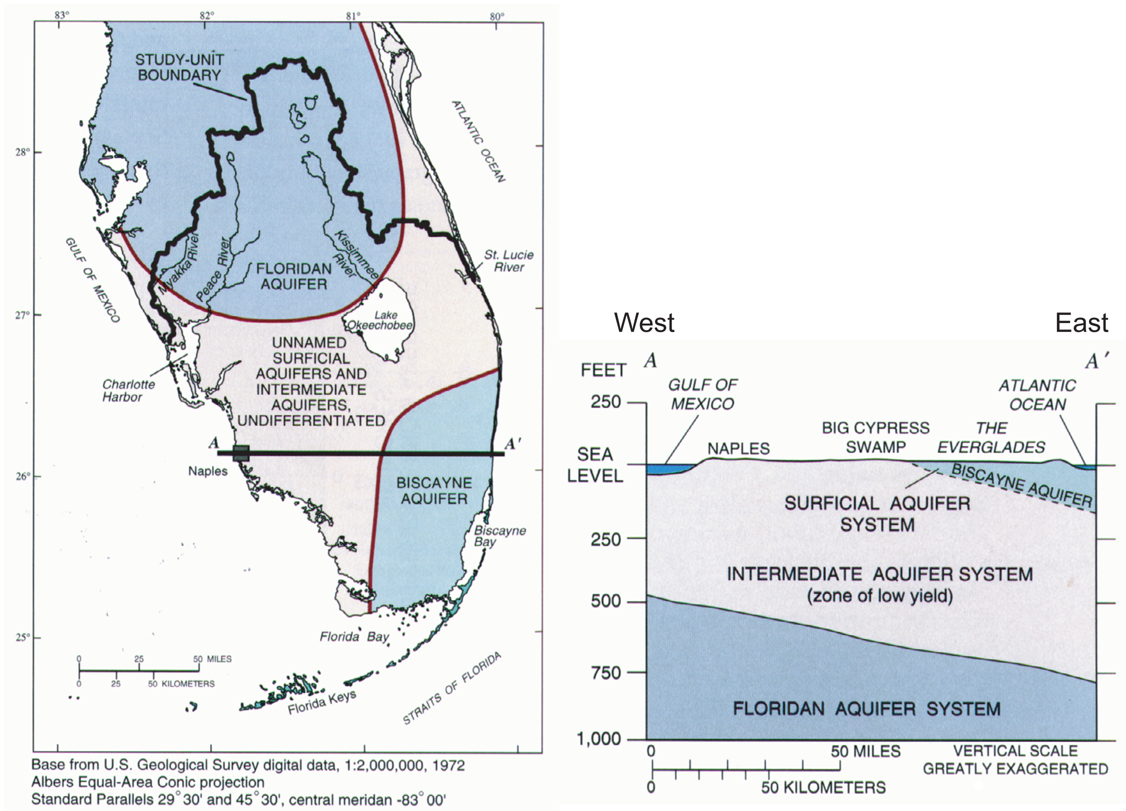


Exhibit ES-5. Conceptual Model of Potential Risks for the Deep-Well Injection Option

DEEP-WELL INJECTION

In South Florida, the most common means of disposal for treated municipal wastewater is by deep-well injection. Deep wells typically inject at depths ranging from 650 to greater than 3,500 feet below land surface, depths that are considerably deeper than the aquifers used for drinking-water supply wells. However, it is acknowledged that in some parts of South Florida, injected water has moved upward into overlying layers and, in some cases, into the base of the area designated as the underground source of drinking water (USDW).

The Upper Floridan Aquifer and the Biscayne Aquifer are the main water sources in the South Florida region (Exhibit ES-6). The Floridan Aquifer is extensive and underlies parts of Alabama, southeastern Georgia, southern South Carolina, and all of Florida. It is divided into the Upper Floridan and Lower Floridan aquifers, which are separated by a middle confining unit.



Source: McPherson et al (2000)

Exhibit ES-6. Hydrologic Profile of South Florida Aquifer System

In the southeastern part of South Florida, the Floridan Aquifer is overlain by a relatively shallow surficial aquifer, the Biscayne Aquifer. In general, the surficial aquifer is composed of relatively thin layers of sands with some interbedded shell and limestone (Exhibit ES-6). The surficial aquifer in Pinellas County is only about 56 feet thick; in Brevard County, it is only 110 feet thick (Exhibit ES-7). The underlying intermediate confining unit, which separates the surficial and Upper Floridan aquifers, is also relatively thin (about 219 feet thick in Pinellas County and 210 feet thick in Brevard County). These hydrogeologic characteristics mean that the surficial aquifer yields only small amounts of water. Thus, it is not a major source for public water supply, although it is used extensively for private water supplies. However, in southeastern Florida, the Biscayne Aquifer is the principal source of drinking water. In this area, both the aquifer and the underlying intermediate confining unit are thicker (more than 230 and 610 feet thick, respectively), which results in an increased water-bearing capacity.

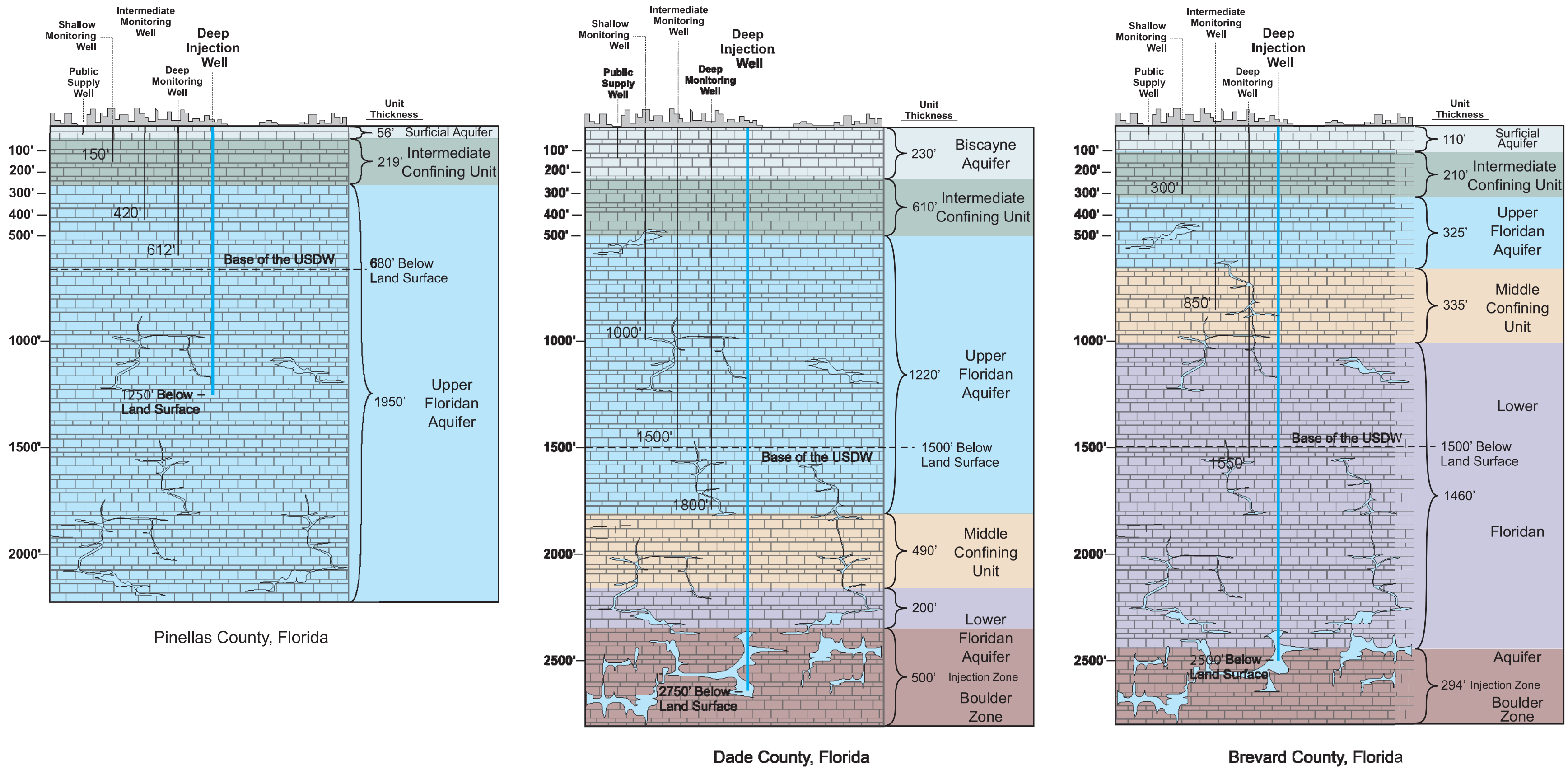


Exhibit ES-7. Representative Hydrogeologic Cross Sections

The presence of the separating confining units (intermediate and middle), combined with the considerable depth to the deep-well injection zones, was considered to provide a sufficient level of protection to the water-bearing strata that supply public water. However, the relative safety of this disposal option is now in question because injected water is known to have migrated up to and, in some cases, into the USDWs.

Deep-well injection fluid is given a secondary level of treatment and the State does not require disinfection, although some facilities may dispose of excess (unused) reclaimed wastewater using Class I deep-well injection. Treatment beyond a secondary level is used to varying degrees in the three other disposal options included in the risk assessment (aquifer recharge, discharge to ocean outfalls, and discharge to surface-water bodies) (Exhibit ES-4).

Many parts of the United States use Class I injection wells for disposal of hazardous and nonhazardous fluids. In Florida, deep-well (Class I) injection is an important management option for treated municipal wastewater and accounts for approximately 20% (0.44 billion gallons per day) of the State's wastewater management capacity (FDEP, 1997). Most of this use occurs in South Florida, particularly southeastern Florida and in coastal areas. The wells inject large volumes of wastes into deep rock formations, which are required to be separated from sources of drinking water by layers of impermeable clay and rock.

The use of Class I wells in South Florida has been considered a safe and effective means of disposing of treated wastewater. However, ground-water monitoring data has indicated that, at some facilities, wastewater is not being adequately confined, resulting in unintended movement of the injected fluid into USDWs. At some locations, injected wastewater has migrated from the injection zone into overlying layers and is compromising USDWs. Of 93 facilities with deep injection wells in South Florida, 18 have been identified as having unintended movement of fluid out of the injection zone: 3 have confirmed fluid movement into the USDW, 6 are reported to have probable movement into the USDW, and 9 have movement into non-USDWs, (layers overlying the injected zone but below the USDW).

Regulatory Oversight of Deep-Well Injection

Federal and State regulations govern the siting, construction, operation, and management of Class I injection wells. A key UIC regulatory requirement prohibits the movement of any contaminant from a Class I injection well into a USDW. UIC regulations also specify well siting requirements, including specifications for constructing wells, for defining hydrologic conditions relative to the site, for ensuring the mechanical integrity of injection wells, and for proper operation and maintenance of wells. Class I injection wells must be cased and cemented to prevent the movement of fluids into or between USDWs. Injection pressures may not cause fractures in the confining zone or cause the movement of injection or formation fluids into a USDW. (40CFR146.12 and 13). In addition, the State requires that all Class I municipal waste disposal wells provide, at a minimum, secondary treatment.

In spite of these many regulations and controls, unintended migration of injected wastewater in South Florida has occurred. Therefore, the ability to maintain sufficient confinement between the injection zone and the USDW is in question.

Option-Specific Risk Analysis for Deep-Well Injection

The risk analysis of deep-well injection focused on Brevard, Pinellas, and Dade counties, because these counties are geographically representative (i.e. they are located in the three corners of the assessment area) and fluid movement, to some degree, has occurred in each location. A large volume of treated wastewater is injected into Class I injection wells. Subsequent migration of this wastewater and any dissolved or entrained wastewater constituents that remain after treatment can lead to exposure for receptors such as USDWs and water-supply wells.

Secondary treatment of wastewater with no disinfection does not remove all potential stressors to human health. Nitrate levels can exceed the Federal and State maximum contaminant level (MCL) for drinking water; pathogenic bacteria and viruses are not inactivated and may exceed standards for drinking water; and *Giardia* and *Cryptosporidium* levels may exceed Florida's health-based (reuse) recommended criteria.

Stressors to ecological health that may remain after treatment are generally limited to nitrates and phosphates. These are considered nutrients for ecological systems. When present in excess concentrations, they can destabilize the natural systems and cause eutrophication of aquatic systems. Given this characterization of the level of contaminants remaining in secondary treated effluent, a next step in the risk assessment was to examine the fate and transport of these contaminants in the sub-surface.

How Injected Wastewater Can Reach Drinking-Water Supplies

In general, injected wastewater can move upwards by porous media flow and by bulk flow. These represent two extremes: porous media flow is a slow fluid movement through connected pores in the rock matrix, and bulk flow is a more rapid flow through preferential paths, such as fissures, fractures, caverns, or channels (Exhibit ES-8). Bulk flow can also occur from improperly constructed and poorly maintained injection-well systems that lead to an incomplete seal between the well and its casing.

In most cases in South Florida, both porous flow and bulk flow mechanisms will contribute to upward migration. However, it is not possible to differentiate the contribution of each for a given location. Bulk flow is likely a major contributing process in South Florida, where there are karst geologic features. The most well known geologic feature in the area that can support bulk flow is the Boulder Zone. Located in the middle section of the Lower Floridan Aquifer (Exhibits ES-7 and ES-8), this highly developed and complex fracture zone has extensive cavernous pores, fractures, and widened joints that allow channelized groundwater flow, sometimes at extremely rapid rates.

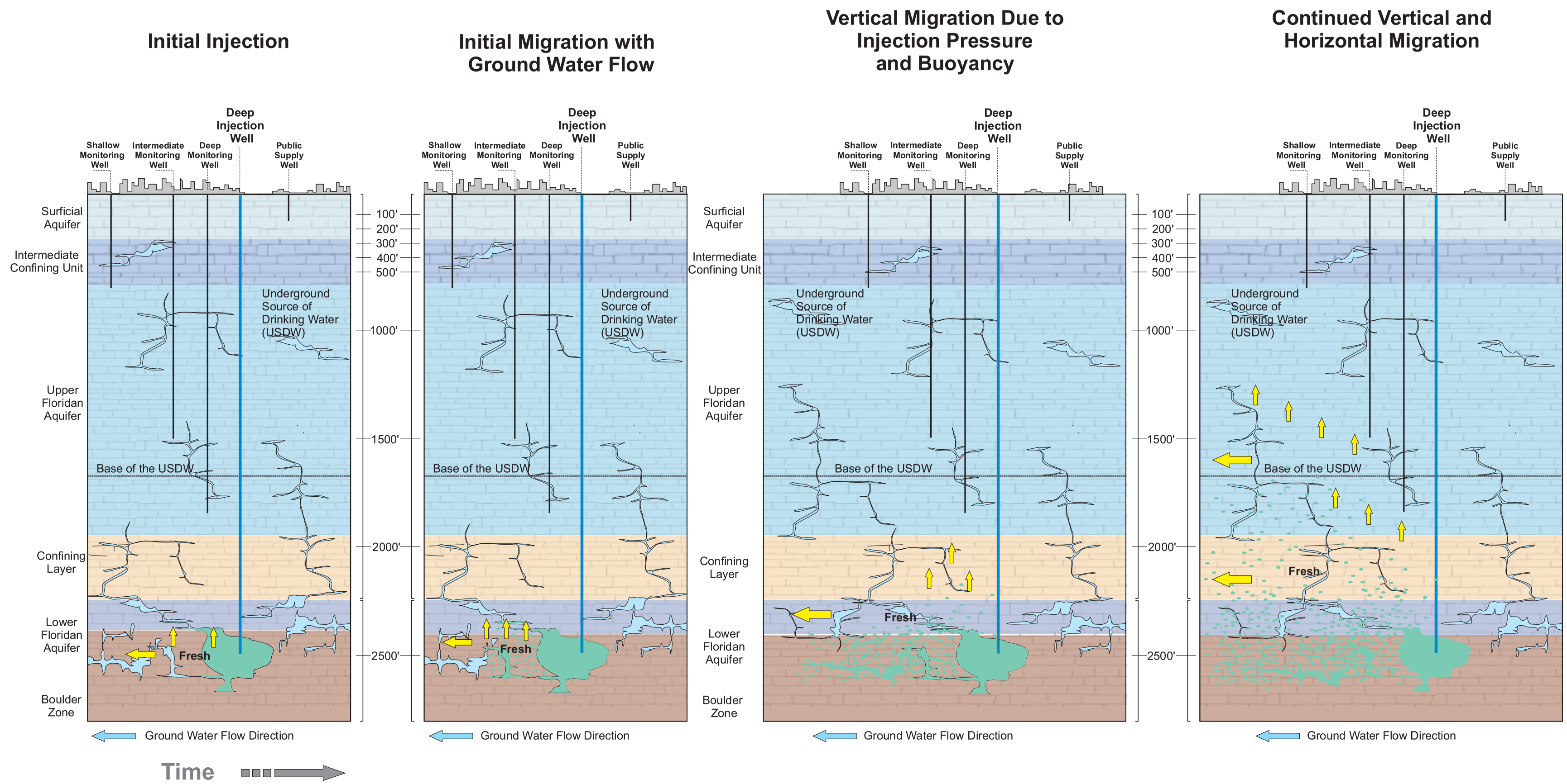


Exhibit ES-8. Migration of Wastewater by Bulk Flow from a Deep-Well Injection Zone. *Bulk flow and porous media flow contribute to migration and are influenced by several factors, including temperature, density, and injection pressure.*

Fluid movement underground is influenced by several factors. Temperature and density differences between native and injected waters affect buoyancy. The fluid density of injected wastewater is roughly equivalent to fresh water. However, wastewater is injected at depths where the native groundwater is saline or hypersaline. Buoyancy tends to force the comparatively lighter, less dense wastewater upward.

Injection pressure also influences fluid movement, but the degree of influence is affected by the geology. In parts of South Florida, where injection zones demonstrate a great capacity to accept injected fluid (for example, the Boulder Zone), the influence of injection pressure may be less significant. Regional differences in the effect of injection pressure were accounted for in the risk analysis by including Dade, Brevard, and Pinellas counties.

The exposure pathway for the stressors found in injected wastewater is upward migration of the injected wastewater into the base of USDWs. In some locations, this upward migration can occur relatively rapidly and with little dilution of stressors. In the area of the Boulder Zone, injected wastewater that has migrated upwards might pose some ecological health risk for the marine environment, were the fluid to migrate more than 2500 feet upward . There is little information currently available to assess such a risk.

Human Health and Ecological Risk Characterization of Deep-Well Injection

Deep-well injection for disposal of treated municipal wastewater has resulted in fluid movement into USDWs. In both Pinellas County and Dade County fluid has moved into the USDW.

The overall human health risk is lower for those USDWs that are deep, and exposure to stressors for currently used drinking-water sources is less likely. The current risk of human exposure is considered lower for Dade and Brevard counties, because the length of time required for contaminants to reach current drinking water supplies is long. However, the time of travel in the Pinellas County area is shorter because of the shallower aquifer depth and lack of confinement. The risk would be therefore higher for Pinellas County and exposure of current water supplies to stressors more likely but for the fact that Pinellas County effluent is subjected to high level disinfection. Failures within the injection system itself clearly increase risk. Improperly constructed or poorly maintained injection-well systems can result in decreased times of travel to receptors and in an associated increase in risks and exposures. However, there is no information to conclude that mechanical failures of Class I municipal waste disposal wells in South Florida have resulted in significant fluid movement into USDWs.

Ecological risk can result from nutrient enrichment of surface waters and the associated ecosystems. However, in South Florida, the risk is considered low because that movement is unlikely. There may be an increased risk in situations where fluid migrates rapidly to surface-water bodies, as in a conduit or a bulk-flow scenario. Nutrient enrichment and other potential impacts to near-shore marine and estuarine environments could occur under such a scenario.

AQUIFER RECHARGE

Any practice that potentially results in the replenishment of a groundwater aquifer can be considered aquifer recharge. Treated municipal wastewater discharged onto the land may percolate through soils and underlying geologic media until it reaches and recharges the surficial aquifer. In Florida, several practices may be considered as aquifer recharge: irrigation, discharge to infiltration basins or absorption fields, and discharge to wetland treatment systems. The State defines reclaimed water as water that has received, at least, secondary treatment and disinfection and is reused after flowing out of a domestic wastewater treatment facility. Reuse is the deliberate application of reclaimed water for a beneficial purpose according to Florida requirements. The final use of the wastewater determines the specific treatment requirements.

Reuse of water for irrigation is significant in Florida. Of a total of 359 reuse irrigation systems, approximately one-half (179) are golf-course irrigation systems, while the other half is divided among irrigation for other public-access areas (98) and residential irrigation (82). Agricultural irrigation systems using reclaimed water number 117.

Reclaimed water is discharged at a rate that prevents surface runoff or ponding and that is within a designated hydraulic loading rate. Loading rates are based on the ability of the plant and soil system to remove pollutants from the reclaimed water, the infiltration capacity, and the hydraulic conductivity of the underlying geology. Slow-rate land application systems must have back-up disposal methods, such as discharge to a storage area or to deep-well injection, for wet-weather conditions and when water-quality treatment standards are not met.

Rapid-rate land application systems discharge reclaimed water to rapid infiltration basins or absorption fields. Infiltration basins operate in series and may include subsurface drains that receive and distribute the water. Absorption fields are subsurface absorption systems covered by soil and vegetation and may include leaching trenches, pipes, or other conduits that receive and disperse water. Rapid-rate systems are potentially high-volume systems. Because of the increased percolation, the loading rates are higher than for slow-rate land application, and rapid-rate systems do not require wet-weather alternatives. For these reasons, EPA focused on rapid-rate infiltration basins (RIBs) for the risk assessment.

Regulatory Oversight of Aquifer Recharge

Aquifer recharge as a wastewater management option is not specifically regulated, but the State regulates the reuse of reclaimed water and land application. State regulations specify system design and operating requirements. Backup treatment and holding capacity is required, in case of system interruption. Slow-rate land application must have back-up wet-weather disposal options. Wastewaters must meet water-quality criteria and must be tested for pathogenic protozoans. Setback distances from surface waters and from potable water sources are required, and Florida's wastewater-to-wetlands rule controls the quantity and quality of treated wastewater discharged to wetlands.

Option-Specific Risk Analysis for Aquifer Recharge

Rapid-rate systems have the potential of discharging large volumes of treated wastewater directly to the surficial aquifer. The public water supply in South Florida is generally drawn from wells about 250 feet deep and located in the surficial aquifer. In Pinellas County, the surficial aquifer is shallow, with a depth of about 56 feet. In Brevard County, the surficial aquifer extends to a depth of 110 feet. In Dade County, the surficial Biscayne Aquifer extends to a depth of 230 feet. Depending upon local groundwater conditions, rapid transport of reclaimed water to these shallow aquifers and current drinking water sources may occur. Similarly, surface-water bodies that are under direct influence of groundwater can be exposed to stressors in the discharged wastewater.

Reclaimed water that is bound for rapid-rate land application must have undergone secondary treatment and basic disinfection, and rapid-rate systems must meet, at the base of the discharge zone, groundwater criteria. Projects with permit applications after January 1, 1996 must provide high level disinfection. As a result, the concentrations of stressors are considerably reduced. Potentially remaining stressors in reclaimed water include metals and other inorganic elements (for example, nitrate, ammonium, phosphate), volatile and synthetic organic compounds, and microorganisms resistant to high-level disinfection. Cyst-forming pathogenic protozoans, such as *Cryptosporidium* and *Giardia,* are resistant to chlorination and basic disinfection and require specialized filtration for removal. Concentrations of these pathogenic protozoans typically meet Florida's health-based (reuse) recommendations in rapid-rate land application waters, but some exceptions have been reported. The disinfection byproducts, trihalomethanes, can pose a human health risk, but the concentrations in reclaimed water rarely exceed the health-based standards.

Just as with deep-well injection waters, stressors to ecological health that may remain in reclaimed water after treatment are nitrates and phosphates. Because they are nutrients, they can destabilize the natural systems and, when present in excess concentrations, can cause eutrophication of aquatic systems. Thus, the next step of the risk assessment, the analysis of the fate and transport mechanisms and a determination of the time of travel, was very important.

The time of travel for discharged effluent to move in groundwater to a receptor is site-specific and dependent on required setback distances, location and distance to receptor water-supply wells, direction of groundwater flow, the actual distance to potential receptor wells, and the aquifer's groundwater flow characteristics.

Natural attenuation processes were also analyzed to determine their affect on final constituent concentrations. Sorption, biological degradation, and chemical transformation of constituents can reduce their overall concentration during transport in groundwater. Rapid-rate infiltration and the associated shorter times of travel tend to limit natural attenuation.

Human Health and Ecological Risk Characterization of Aquifer Recharge

Because of the level of treatment, reclaimed water contains relatively few stressors, which generally are at reduced concentrations. Many constituents remaining in the treated wastewater are at levels that meet the respective drinking-water standards (MCLs). The average concentrations of the cyst-forming *Giardia* protozoan meet risk-based criteria. However, monitoring data from reuse facilities indicate the presence of *Giardia* in 58% of the samples, with detections frequently exceeding the stated recommendation of 1.4 cysts per 100 milliliters.

Although time of travel may be relatively short for some locations and indicate a higher potential risk, a high effluent transport rate does not result in a greater overall risk. Dade County, where the Biscayne Aquifer has a high hydraulic conductivity, has the shortest estimated travel times for treated effluent in groundwater to reach drinking-water supply wells: 0.11 year for a 200-foot setback, 0.28 year for a 500-foot setback, and 1.47 years for a 2,640-foot setback. In spite of these relatively short times of travel, there is little overall risk, because the final concentrations of stressors are below the respective drinking water standards (MCLs).

DISCHARGE TO OCEAN OUTFALLS

Six publicly owned wastewater treatment facilities located in coastal southeastern Florida currently use ocean outfalls to dispose of treated municipal wastewater. The total volume discharged is about 310 mgd. Before discharge, the wastewater undergoes secondary treatment, followed by basic disinfection. The treated wastewater is discharged through outfall pipes into the ocean at depths ranging from 27.3 to 32.5 meters and at distances between 0.94 and 3.56 miles from shore.

The outfalls discharge into the Florida Current, which flows northward to join the Gulf Stream. Circulation created by the Florida Current and associated eddy and rotary flows is important and the western boundary of the current is a major nutrient source for ocean productivity. Effluent discharged from the outfall forms a characteristic plume that tends to rise in seawater because it is less saline. However, the effluent is rapidly diluted and mixed with ocean water (Exhibit ES-9). The speed and direction of the currents are the primary factors that govern plume dispersal.

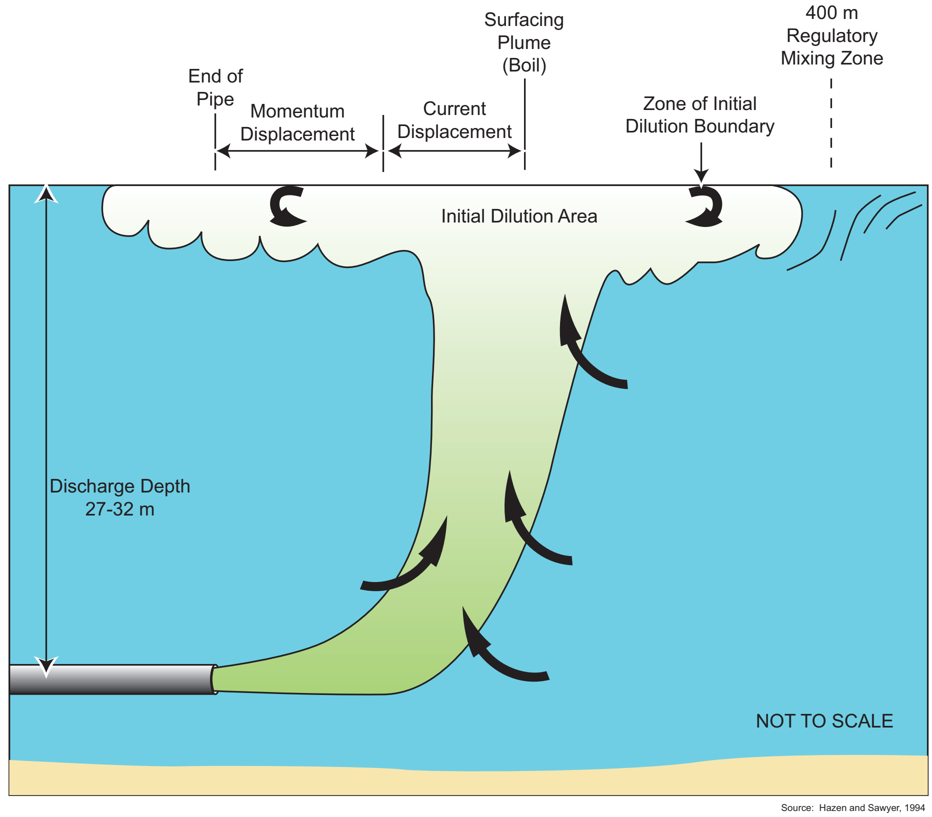


Exhibit ES-9. Effluent Plume Characteristics for Ocean Outfalls

The risk assessment for this option mainly focused on the potential effects on the marine environment. Discharge to the ocean has no effect on sources of drinking water. The receptors considered in this option are those that may have a direct exposure to seawater containing effluent constituents.

Regulatory Oversight of Discharge to Ocean Outfalls

The Clean Water Act and Florida law require that municipal wastewater receive at least secondary treatment before discharge to the ocean. When chlorine is used as a disinfectant, it must be used at the minimum concentration necessary to achieve water-quality standards. Higher concentrations of chlorine may lead to the production of trihalomethanes, which are a human health risk.

State-designated Class III Waters are used for recreation and for the propagation and maintenance of a healthy, well-balanced population of fish and wildlife. Effluent discharged into the ocean must meet the Class III standards for total suspended solids and for a 5-day biological oxygen demand.

There are additional requirements for the effluent when it meets the receiving waters. There are State and Federal water-quality criteria for effluent water at the end of the outfall pipe, within the mixing zone, and at the edge of the mixing zone. At the edge of the mixing zone, Federal, State, and local regulations require that the water meet surface-water quality standards.

Option-Specific Risk Analysis for Discharge to Ocean Outfalls

The focus of the risk analysis was the potential effects that discharges to the ocean may have on ecological receptors. In Florida, ocean waters are not currently used as a source for drinking water. Therefore, the ocean discharge option is not a human health risk through the drinking-water supply. Human exposure to seawater that contains effluent constituents may occur for recreational users (fishermen, boaters, and swimmers), industrial fishermen, and outfall operators and workers. Exposure may be through dermal contact, incidental ingestion of ocean water, ingestion of contaminated fish or shellfish (near or removed from the point of discharge), or exposure to toxins produced by harmful algal blooms. Ecological receptors include fish and other organisms that occur around the ocean outfall discharge point as well as those that are removed from the outfall but may be affected by the discharge.

Effluent constituents discharged to the ocean are those that typically remain after secondary treatment and basic disinfection: nutrients, inorganic and volatile organic compounds, synthetic organic constituents, metals, and microbial and miscellaneous constituents. The use of disinfection in addition to the secondary treatment reduces the concentrations of the bacterial and viral stressors; however, the disinfection byproduct, trihalomethanes, may occur. Trihalomethanes, a type of organic compound, can pose a human health risk. Although information is lacking, they may also be a health risk to marine life, such as marine mammals. Cyst-forming pathogenic protozoans, such as *Cryptosporidium* and *Giardia,* are resistant to chlorination and require specialized filtration for removal, and therefore, may be present as a stressor.

Potential receptors in the marine environment are numerous and range from submerged aquatic vegetation, plankton (phytoplankton, zooplankton), and larger aquatic organisms, including invertebrates, fish, reptiles, birds, and marine mammals.

Inorganic constituents, such as nitrogen and phosphorus, and metals, such as iron, are nutrients. However, if they are overabundant, they become stressors. In marine and coastal environments, eutrophication can occur when excess nutrients are present. This can produce harmful algal blooms (red tides), change the natural phytoplankton communities, destroy coral reefs, degrade sea grass and algal beds, and destabilize the overall marine community structure.

Dilution and transport, which are controlled for the most part by ocean currents, are important factors included in the risk analysis. Rapid dilution of effluent can reduce or eliminate potential adverse effects on receptors. In addition, chemical and biological processes that have the potential to affect the level of stressors were included in the risk analysis.

Human Health and Ecological Risk Characterization of Discharge to Ocean Outfalls

The risks associated with discharging effluent using ocean outfalls are low for both human and ecological receptors. There is no drinking-water receptors associated with ocean disposal and therefore, exposure through this pathway is unlikely.

Effluent plumes are rapidly dispersed and diluted by the Florida Current, and flows towards coastal areas are infrequent because of the current's prevailing direction and speed. The concentrations of potential stressors in the effluent plume are low, because of the secondary treatment and disinfection, permit effluent concentration limits, and the subsequent dilution of the effluent after discharge. The distances of the outfalls from shore also decrease risk, with those more distant having the lowest risk. Outfalls that have multiport diffuser systems seem to further reduce risk by dispersing the effluent over a wider area further reducing concentrations of potential stressors.

The treatment level used in ocean disposal does not remove certain pathogenic protozoans that could potentially affect human and ecological health. Pathogenic protozoans may pose a risk to marine mammals that come in contact with the effluent constituents. However, there is a lack of ecological health information on the effects of pathogenic protozoans, as well as other stressors, including metals, endocrine disruptors, and surfactants. Although the concentrations of these compounds may meet required water-quality standards, their effect on biological receptors at low concentrations is not understood. For example, endocrine disruptors operate at extremely low concentrations.

Although chlorinated effluent meets water-quality standards generally within 400 meters of the outfall, the long-term ecological effects of discharging effluent into the ocean are not understood. Currently, there are no long-term monitoring data available for these discharges to describe the ecological impacts or to determine what interaction there is, if any, between outfall constituent effects and terrestrial or coastal sources (such as pesticide runoff or river and groundwater inputs).

DISCHARGE TO SURFACE WATERS

Surface water disposal involves discharging treated wastewater directly into canals, creeks, and estuaries that may be brackish, coastal/saline, or fresh water. The wastewater must receive at least secondary treatment and basic disinfection before discharge. Advanced wastewater treatment is required in some locations.

The use of this option in South Florida varies greatly. Treatment facilities in Hillsborough County rely on this option for about 75% of their total design capacity, whereas facilities in Collier County discharge to surface waters about 1% of their design capacity.

Surface waters that receive discharges vary in physical, chemical, and biological characteristics. As a result, the uses and applications of this disposal option are very site-specific. The estuarine and lagoon systems that receive discharges are typically large expanses of mostly shallow water. Tampa Bay is the largest open estuary in Florida, encompassing over 400 square miles, with an average depth of 12 feet (Pribble et al., 1999). Sarasota Bay is about 56 miles long and about 300 feet to 4.5 miles wide. It has an average depth between 8 and 10 feet (Roat and Alderson, 1990). The Indian River Lagoon is comprised of several water bodies and stretches for about 156 miles, from south of Daytona Beach to near Palm Beach (Adams et al., 1996). Effluent entering these three major surface water systems must undergo advanced wastewater treatment.

These shallow surface-water bodies include many different and extensive features, such as wetlands, lakes, streams, and canals. In South Florida, many of these surface-water bodies have direct hydrologic connections to the underlying surficial aquifers.

Regulatory Oversight of Discharge to Surface Waters

Florida regulations require that wastewater receive at least secondary treatment and basic disinfection before discharge. Discharge to Class I waters (potable water supply) requires principal treatment, (defined within State requirements as secondary treatment, basic disinfection, filtration and high level disinfection) and discharges to the Tampa Bay, Sarasota Bay, and Indian River Lagoon systems require advanced wastewater treatment. Additional permitting requirements may include that effluent meet certain effluent limits, such as technology-based effluent limits or water-quality-based effluent limits.

State-mandated discharge standards apply for overall pollutants, nitrogen, total suspended solids, and fecal coliforms. Currently, there are no Federal or State limits for protozoan pathogens in wastewater but Florida applies its reclaimed water standard (no more than 5.8 cysts or oocysts per 100 liters for *Cryptosporidium* and no more than 1.4 cysts per 100 liters for *Giardia*) to wastewater discharged to surface waters.

Water-quality standards also apply to discharges to surface waters. The standards are dependent on the end-use class of the receiving surface water. The following classes are relevant to the risk assessment: Class I surface waters may be used as a potable water supply; Class II waters may be used for shellfish propagation or harvesting; Class III water may be used for recreation or can support the propagation and maintenance of a healthy, well-balanced population of fish and wildlife.

Option-Specific Risk Analysis for Discharge to Surface Waters

Because of the variability between and within the receiving surface waters and the regulatory standards governing them, the human health and ecological risks associated with this option are site-specific. To overcome this challenge, surface-water quality was the major parameter used in the risk analysis. The water quality of discharges was compared to the relevant surface-water quality standards. The risk analysis also examined the types of adverse effects that might be anticipated when standards are exceeded.

The potential stressors associated with this option can vary substantially, depending upon the level of treatment applied to the wastewater, but may include nutrients (nitrogen and phosphorus), metals, organic compounds, pathogenic microorganisms, and hormonally active agents. Metals remaining in discharged effluent may be taken up and bioaccumulate in the food chain to potentially toxic levels. Excess nutrients, particularly nitrogen and phosphorus, are stressors and can have a significant effect on aquatic ecosystems. Excess nutrients can change biological productivity and community structure and cause harmful algal blooms.

Before discharge to surface water, wastewater must undergo secondary treatment and basic disinfection. Stressors in wastewater subjected to secondary treatment and disinfection are similar to those remaining in water bound for ocean disposal, that is, inorganic and volatile organic compounds; synthetic organic constituents; microbial and miscellaneous constituents; and trihalomethanes, a disinfection by-product. However, wastewater discharged to Tampa Bay or to Indian River Lagoon must be treated using advanced wastewater treatment. This typically includes secondary treatment, basic disinfection, nutrient removal (nitrification, denitrification, and phosphorus removal), removal of metals and organic compounds, and filtration to remove cyst-forming protozoans.

In many cases, it is not possible to identify the source of stressors in surface waters. In South Florida, surface-water quality shows significant degradation that may be from urban and agricultural activities (McPherson et al., 2000; McPherson and Halley, 1996). Canal water in urban and agricultural areas commonly contains high concentrations of nutrients, coliform bacteria, metals, and organic compounds when compared to water taken from remote areas. The relative contribution of stressors from these sources compared to the contribution from effluent discharge is poorly understood.

Contamination of Florida's coastal environments with enteric viruses, bacteria, or protozoans is a widespread and chronic problem. Potential causes include the prevalence and high density of septic systems, the predominantly porous and sandy soils, the karst topography, and the hydrologic connections between groundwater and coastal embayments and estuaries (Lipp et al., 2001; Paul et al., 1995). The disinfection of treated effluent before discharge eliminates most pathogens. However, pathogenic protozoans are resistant to disinfection and can persist in effluent.

Under optimal natural conditions, estuaries and lagoons are some of the most productive and diverse habitats. Potential receptors are many and range from microscopic phytoplankton and submerged aquatic vegetation to reptiles, birds, marine mammals, and humans. Threatened and endangered species, such as the West Indian manatee and green and loggerhead sea turtles, can be found in these estuary and lagoon areas. Of the almost 800 fish species known to occur in east-central Florida, more than half use the estuaries and lagoons during part of their life cycle (Gilmore et al, 1981; Gilmore 1995). These shallow waters are important breeding and spawning areas for many fish.

USDWs or water-supply wells may be affected where surface waters that receive effluent have a direct hydrological connection to the groundwater resource. In South Florida, there is a strong interconnection of groundwater and surface water, but the processes and hydrologic fluxes are not well understood. Canals, which frequently receive discharge, are often hydrologically connected to groundwater. Whether the canal is being recharged or is discharging to groundwater depends on the specific hydrologic conditions, but canals that discharge to groundwater provide a pathway for potential contamination of the underground drinking water supply.

In addition to USDWs, human health exposure can include dermal contact with an affected water body, incidental ingestion of affected water, ingestion of contaminated fish or shellfish (near or removed from the point of discharge), or exposure to toxins from harmful algal blooms. Ecological resources can include fish and other organisms present in the surface water body at the point of discharge as well as those that are removed from but may be affected by the discharge. Also, nutrient loading can adversely impact waters, especially sensitive or impaired waters, and this in turn can destabilize the aquatic system.

Human Health Risk and Ecological Risk Characterization of Discharge to Surface Waters

Effluent discharged to surface waters poses limited risks to human health. The volumes discharged in South Florida are not great, there is a generally higher level of effluent treatment, and the discharges are typically intermittent. Although not required at all treatment plants, AWT is used to remove additional nutrients, organic compounds, and total suspended solids. Facilities using this treatment level frequently are within the standard requirements and may be below detection levels for some effluent constituents (for example, pathogenic microorganisms, inorganic compounds, organic compounds, volatile organic compounds). Pathogenic protozoan levels are generally low and usually within recommended standards. However, some facilities did not meet the recommended levels, even when using filtration. In these cases, there is a potential human health risk, albeit a low risk.

Similarly, the overall risk to ecological receptors is low. This is because most facilities use AWT. For example, based on information collected before and after Tampa Bay implemented AWT, the relative risk of AWT-treated wastewater is lower than the risks posed by wastewater treated to a lesser degree.

Although the risk analysis identified limited human health and ecological risks associated with the discharge of treated effluent to surface-water bodies, the receiving surface waters in many cases are already significantly impacted by contamination from urban and agricultural sources. Additional inputs of nutrients, even from effluent containing low nutrient concentrations, are likely to pose some ecological risk. The cumulative effect of the various inputs into these surface waters is not currently understood. Considerable scientific study and public involvement would be needed to identify and address the problems associated with the relative contributions of different sources of stressors to these estuarine and lagoon waters.

OVERALL RISK ASSESSMENT

The degree of treatment of wastewater before its disposal is an important factor that controls the concentrations of stressors present at the receptor. Risk can be significantly reduced by attenuation factors, such as travel time, distance, filtration by geologic media, dispersion by groundwater or ocean currents, biological degradation, and adsorption.

Pathogenic microorganisms pose a significant human health risk for deep-well injection and discharge to ocean outfalls and, to a lesser extent, aquifer recharge and discharge to surface waters. Filtration can significantly reduce the level for pathogenic protozoans in treated water. However, natural water bodies may contain pathogenic protozoans at levels that exceed the recommended levels.

In addition, nutrient levels can still exceed ambient water-quality levels. Excess nutrients can lead to a variety of ecological problems and can affect entire ecosystems.

Most risk analyses have data and knowledge gaps, and it is important to acknowledge and understand their extent and type. This risk assessment identified data and knowledge gaps for all the options (Exhibit ES-10).

Deep Well Injection	Aquifer Recharge (using RIBs)	Discharge to the Ocean	Discharge to Surface Waters
Site-specific mechanisms of transport (for example, porous media flow vs. conduit flow); locations and connectivity of natural conduits such as solution channels. The fate and transport of pathogenic microorganisms; rates of die-off and natural attenuation. The extent of, if any, reduction in inorganic stressor concentration resulting from local geochemical conditions (for example, rate of biologically mediated transformation of ammonia). Groundwater monitoring data to describe transport to (or within) the Biscayne and surficial aquifers.	Site-specific hydrologic data (for example, horizontal hydraulic conductivities); site-specific estimates of horizontal time-of-travel. Groundwater monitoring data to describe transport within the Biscayne and surficial aquifers. Geospatial data to describe proximity to water-supply wells (especially private wells). Fate and transport of pathogenic micro-organisms still present after disinfection; rates and die-off.	The potential for adverse ecological effects near outfalls. The potential for bioaccumulation (such as metals, persistent organic compounds) through food chains. Water-quality and ecological monitoring downcurrent of outfalls (beyond mixing zones). The potential for changes in ocean currents, sea level, or climate that might affect changes in circulation and transportation patterns or exposure.	The potential for adverse ecological effects near points of discharge. The potential for bioaccumulation (such as metals, persistent organic compounds) through food chains. Water-quality and ecological monitoring data for specific potentially impacted water bodies. The nature and extent of recharge to surficial USDWs.

Exhibit ES-10. Data and Knowledge Gaps

Findings on Risk to Human Health

Overall, the risks to human health are generally low for the four disposal options (Exhibit ES-11). The risks are somewhat higher in all options when there is less treatment or when exposure pathways are short. High-level disinfection, combined with filtration for pathogenic protozoans (using an effective process), significantly reduces risk for all the disposal options. There is an increased risk to human health when the disposal location coincides with recreational uses, such as the ocean (outfall location), canals, streams, bays, and lagoons, and when discharges cause harmful algal blooms. Deep-well injection and aquifer recharge disposal options have the potential to directly impact drinking-water supplies, thereby creating a potential risk to human health.

Deep-Well Injection	Aquifer Recharge (using RIBs)	Discharge to the Ocean	Discharge to Surface Waters
Low where proper siting, construction, and operation result in physical isolation of stressors, with no fluid movement. Low where there have been impacts to deep USDWs; however, exposure of current water supplies is unlikely. Increased risk where short times of travel prevail and where exposure of current water supplies is more likely. In all cases, the risk would be further reduced when injected wastewater is treated to reclaimed water standards.	Low because of high-level disinfection, filtration, and treatment to reclaimed-water standards. Increased risk where filtration is not adequate to meet health-based recommendations for Giardia or Cryptosporidium. Increased risk where chlorination results in high levels of disinfection byproducts (that is, failure to dechlorinate).	Low because of rapid dilution and an absence of drinking-water receptors. The low occurrence (less than 4%) of current flow towards the coast means that human exposure along coastal beaches is reduced. Increased risk where recreational use is near the discharge. Increased risk where discharges contribute to stimulation of harmful algal blooms.	Low because of high-level disinfection and additional treatment (e.g. AWT standards). Increased risk where filtration is not provided or is inadequate to meet health-based recommendations for Giardia or Cryptosporidium. Increased risk where surface-water discharges are near recreational use of water bodies. Increased risk where discharges contribute to stimulation of harmful algal blooms.

Exhibit ES-11. Estimate of Risk to Human Health Associated With Each Wastewater Disposal Option

Findings on Risk to Ecological Health

The risk to the ecological health of surface waters is very low for the deep-well injection and aquifer recharge options (Exhibit ES-12). Similarly, the risk to surface waters receiving treated discharge directly is low because of the advanced level of treatment the wastewater receives. However, irrespective of the contribution of contaminants by treated municipal wastewater, many surface waters in South Florida are considered to be in an impaired status. When a discharge is in close proximity to an impaired water body, there is a higher ecological health risk.

Deep-Well Injection	Aquifer Recharge (using RIBs)	Discharge to the Ocean	Discharge to Surface Waters
The risks from chemical constituents are low but not zero because of possible hydrologic connectivity. Risks related to pathogenic microorganisms are low to moderate for Dade and Brevard counties because of lack of disinfection and filtration. Microbial risk is low in Pinellas County because of use of disinfection and filtration.	Low because of possibility of hydrologic connectivity between wetlands and surficial aquifer. Cumulative and long-term effects are not known.	Low because of the concentrations of nutrients in the discharged effluent. No ecological monitoring is currently conducted. Cumulative and long-term effects are not known.	Low because of the concentrations of nutrients in the discharged effluent.

Exhibit ES-12. Estimate of Risk to Ecological Health Associated With Each Wastewater Disposal Option

Risks are also considered low for ocean outfalls in the areas outside the mixing zones and for marine ecosystems that may be impacted by deep-well injection.

Discharges from ocean outfalls and discharges to surface waters will have increased risk if the discharges cause harmful algal blooms or result in bioconcentration in food webs. Construction of new ocean outfalls may increase risk to coral reefs.

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